

Evaluation of the antioxidant power and the content of secondary metabolites of the crude compounds of *Talinum triangulare* (Talinaceae), a plant with antiplasmodial activity

Abstract

Talinum triangulare is a food plant recognized for its nutritional properties and therapeutic virtues. This plant is used in particular in Daloa (Central-West Ivory Coast) by naturotherapists, for the treatment of malaria. This study aimed to evaluate the antioxidant activity of extracts and fractions of *Talinum triangulare* leaves and to determine their content of secondary metabolites. Two methods were used for this evaluation: reduction of the 2,2'-diphenyl-1-picrylhydrazyl radical (DPPH) and reduction of the ABTS⁺ cation radical (2,2'-azinobis-3-ethylbenzothiazoline-6-sulfonic acid).

The results show that the IC₅₀ could not be determined for the 70% aqueous and hydro-ethanolic extracts with the DPPH test, while it was respectively 0,9 and 2,3 mg/mL for the fractions dichloromethane and aqueous. Regarding the ABTS⁺ radical-cation reduction test, the dichloromethane fraction showed a higher percentage of inhibition (41,59%) compared to the aqueous fraction (40,59%), while the aqueous fraction was a little more important than the hydro-ethanolic extract at 70 % (38,29%). Among the four compounds tested, only the aqueous extract presented a relatively low percentage of inhibition (25,51%).

Spectrophotometric analysis revealed the presence of various phenolic compounds, such as flavonoids, polyphenols and total tannins, at varying concentrations. These results could support the traditional use of *Talinum triangulare* in the treatment of malaria.

Key words: *Talinum triangulare*, antioxidant activity, phenolic compounds.

INTRODUCTION

Over the past twenty years, the incidence of parasitic diseases has increased. Malaria is among these parasitic diseases. Despite being entirely preventable and treatable, it continues to have devastating consequences on the health and livelihoods of populations across the world (Tagne, 2021). This state of affairs has led authors to affirm that this disease is “one of the rare public health scourges that has survived the centuries without ever losing its activity” (Gentilini and Dufflo, 1993; Bagayoko, 2008). Unfortunately, its management faces resistance from most antimalarial drugs (WHO, 2023). It is therefore crucial to search for new active molecules and medicinal plants appear to be an important source to explore.

Furthermore, natural therapies based on medicinal plants are of great benefit. They are better biodegradable and are suspected of having resistance-reversing properties. In addition, the best treatments recommended by the WHO for the therapeutic management of malaria are based on derivatives of molecules from medicinal plants (Salery, 2007; Tano, 2016).

According to the World Health Organization (WHO), more than 80% of the African population uses traditional medicine for their primary health care due to their proximity and accessibility (Nkasa et al., 2020). Ivory Coast is one of the third world countries where medicinal plants are commonly used to solve health problems, especially in rural areas. This is how a significant number of works relating to the biological, pharmacological and phytochemical properties of plants from traditional Ivorian medicine have been carried out. The data provided by these studies made it possible on the one hand to explain the therapeutic action and on the other hand to confirm the use of these different plants in traditional medicine (Mariam et al., 2024). *Talinum triangulare*, a cosmopolitan weed of the *Talinum* genus, of the *Talinaceae* family (formerly *Portulacaceae*), fits into this theme. This plant has great therapeutic values in the traditional medicine system, but is not yet fully exploited (Swarna et al., 2013). Preliminary work carried out on the aqueous and hydro-ethanolic extracts (70%) of its leaves made it possible to demonstrate the antimalarial properties of the leaves of this plant on clinical isolates of *Plasmodium falciparum* (Okou et al., 2019). According to the work of Tano (2016), when a person has an attack of malaria, plasmodia can lead to oxidative stress through the massive lysis of red blood cells. Hemmer et al. (2005) also demonstrated that neutrophils activated by parasites can trigger the destruction of endothelial cells. This can be prevented by *ex vivo* intake of antioxidants and proteolytic enzyme inhibitors. In sum, antioxidants can attenuate endothelial cell damage due to parasite-induced leukocyte activation, supporting the importance of antioxidant activity in the context of malaria treatment (Pincemail et al. 2002). The present study is part of continuing investigations into the antimalarial activity of *Talinum triangulare*. More specifically, the aim was to evaluate the antioxidant activity of extracts and fractions of *Talinum triangulare* leaves and to determine their contents of phenolic compounds, particularly total polyphenols, total flavonoids and total tannins.

1- Material

1-1 Plant material

The plant material consists of leaves of *Talinum triangulare*, belonging to the *Talinaceae* family and well known under the name wild spinach.

1-2 Technical equipment

Most of the technical equipment is made up of:

- Retsch type mechanical crusher to make dried plant material into powder;
- Moulinex type mixer for maceration;
- an electronic scale for the various weighings;
- a Drying Oven DHG-9013A type oven for drying extracts;
- an IKA® MS 3 digital vortex for homogenization;
- a water bath for regulating the temperatures of the environments;
- a Mindray MR-96A type spectrophotometer for reading the different optical densities.

1-3 Reagents and solvents

The main part of the reagents consists of: 2,2'-azinobis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS), DPPH (2,2'-diphenyl-1-picrylhydrazyl), potassium persulfate, Vitamin C, Folin - Ciocalteu, sodium carbonate, gallic acid, sodium nitrite (NaNO₂), aluminum chloride (AlCl₃), sodium hydroxide (NaOH 1N), distilled water, ethanol, methanol, dimethylsulfoxide (DMSO), hexane, dichloromethane, acetate ethyl, butanol.

2- Methods

2-1 Harvesting, drying and spraying *Talinum triangulare* leaves

The leaves of *Talinum triangulare* were harvested between July and August 2021 at the start of the morning (6:30 a.m.) in Koffikro, a camp located 12 km from the Daloa Department and in the Tazibouo district within the UEESO-CI city near COPRO college of Daloa Department (Haut-Sassandra Region, Ivory Coast). After harvest, they were freed of all other elements, dried in the shade and in the open air for ten weeks then crushed until a fine powder was obtained using a mechanical grinder. The resulting powder was stored at room temperature in glass jars to avoid mold.

2-2 Preparation of extracts and fractions of *Talinum triangulare* leaves

The extraction of the active ingredients was generally done by cold maceration in a given solvent using a blender for a specific time.

2-2-1 Preparation of the aqueous extract

The fine powder initially obtained was extracted using the method of Zirihi et al. (2003). To do this, a quantity of one hundred grams of the vegetable powder was cold macerated in one liter of distilled water using a blender. After three minutes of homogenization, the

homogenate obtained was collected in a square of clean white tissue and then pressed by hand. The collected solution was filtered twice through hydrophilic cotton and then once through Whatman filter paper (3 mm). The filtrate obtained was dried in an oven at a temperature of 60 °C for (five) 5 days to obtain the total aqueous extract (Aq).

2-2-2 Preparation of the hydro-ethanolic extract

It followed the same principle as the previous one, with the only difference that instead of water, an ethanol-water mixture (70/30: v/v) was used. It made it possible to obtain the hydro-ethanolic extract (HOH) after drying for 72 hours in an oven at 60°C.

These two extracts (Aq, HOH) were stored separately in airtight jars at laboratory temperature.

2-2-3 Fractionation of the hydro-ethanolic extract

Previous work by Okou *et al.* (2019) revealed that the hydro-ethanolic extract (HOH) had more antiplasmodial action than the aqueous extract (Aq). It is on the basis of these results that the hydro-ethanolic extract (HOH) underwent partition chromatography, using solvents of increasing polarity such as hexane, dichloromethane, ethyl acetate and butanol. It is a partition method which consists of liquid-liquid partitioning with solvents that are immiscible with each other. It was inspired by that of Bolou *et al.* (2011). For its production, a quantity of one hundred grams of the hydro-ethanolic extract (HOH) was dissolved in 500 mL of distilled water then transferred to a 1000 mL separating funnel. Then, to the aqueous solution obtained, 250 mL of hexane was added then the whole was stirred vigorously for five minutes then allowed to settle for a time in order to have a hexanic phase and a residual aqueous phase. After which, the tap of the separating funnel was opened to let the residual aqueous phase pass into a beaker and then the supernatant (hexane phase) was also collected in another beaker. After this first operation, the second consisted of transferring the new residual aqueous phase once again into the separating funnel and then adding 250 mL of hexane again. Then, the whole was vigorously homogenized for five minutes and then left to settle for a while in order to have a new residual hexanic and aqueous phase. After this step, the tap was reopened as before to recover the new residual aqueous and hexanic phases separately in various beakers. The third and final operation was identical to the second in order to obtain the previous results. After these various operations, all of the hexane phases were brought together and subsequently evaporated to constitute the hexane fraction. As for the residual aqueous phase obtained after these various leachings with hexane, it was also subjected to the same previous leaching step three times, but this time successively with dichloromethane,

ethylacetate and butanol. with the aim of having their respective phase (dichloromethane, ethylacetate, butanolic and residual aqueous). The different phases obtained were then evaporated separately in order to obtain their respective fraction (dichloromethane (DCM), ethylacetate, butanolic and aqueous fraction (Faq)).

2-3 Antioxidant activity

2-3-1 Measurement of antioxidant activity by the DPPH test

The DPPH method is a test for the reduction of the 2,2-diphenyl-1-picrylhydrazyl (DPPH•) radical to 2,2-diphenyl-1-picrylhydrazine (DPPH-H). It makes it possible to evaluate the antioxidant potential of a sample, by its capacity to trap the DPPH• radical used as a chromogen (Brand-Williams et al., 1995; Benzie and Szeto, 1999). This organic radical is stable at room temperature and has a purple color. The antioxidants present in the sample, by transferring an H atom to the DPPH• radical, reduce it to DPPH-H or DPPH₂. This reduction causes a change in the color of the solution from purple to pale yellow (Molyneux, 2004). For its production, a quantity of 4 mg of DPPH powder was dissolved in 100 mL of methanol, homogenized then stored away from light to constitute a solution. At the same time, a quantity of 30 mg of each extract to be tested was diluted in 3 mL of sterile distilled water in order to have an extract concentration of 10 mg/mL. Then, a volume of 1,5 mL of methanol was distributed into ten sterile test tubes numbered from 1 to 10 to constitute the experimental series of a given extract. In tube 1 of the experimental series, a volume of 1,5 mL of the extract with a concentration of 10 mg/mL previously prepared was added and then mixed to constitute the stock. It consisted of taking 1,5 mL from tube 1, diluting it in tube 2 then homogenizing it. This operation was repeated up to tube 10. From tube 10, the excess volume was rejected. Thus, the various concentrations varied from 10 to 0,019 mg/mL from tube 1 to tube 10. After which, a volume of 1,5 mL of DPPH was added to every 10 tubes. Alongside this experimental series, a reference series was produced. In fact, it consisted of using vitamin C instead of the plant extract, and always in 10 tubes. The only difference between the experimental and reference series is that the concentrations of the reference product used ranged from 25 to 0,195 µg/mL from tube 1 to tube 10. However, in parallel with the experimental and reference series, a control control was prepared by soliciting only methanol and DPPH at equal volume (1,5 mL). All of the tubes were kept away from light for 30 minutes then their absorbance was determined distinctly with a spectrophotometer at 517 nm with methanol as the blank control and vitamin C as a positive control. The percentage of inhibition of the DPPH radical was calculated according to the

following equation: solution. After this step, the double dilution technique of geometric ratio $\frac{1}{2}$ in medium was applied :

$$\text{DPPH inhibition (\%)} = (A_0 - A_{\text{sample}}) / A_0 \times 100$$

A_0 : absorbance of the control (drug-free). A_{sample} : absorbance of the sample after 30 min.

2-3-2 Measurement of antioxidant activity by ABTS

The method used was that described by Choong *et al.*, (2007). It is based on the ability of compounds to reduce the ABTS⁺ cation radical (2,2'-azinobis-3-ethylbenzothiazoline-6-sulfonic acid). It was produced by the reaction of 8 mM ABTS (87,7 mg in 20 mL distilled water) and 3 mM potassium persulfate (0,0162 g in 20 mL distilled water) in a 1:1 ratio (v/v). The mixture was then incubated in the dark at room temperature for 12 to 16 hours to obtain an ABTS⁺ solution. It was diluted with methanol to obtain a solution whose absorbance was $0,7 \pm 0,02$ at 734 nm. Then, a volume of 3,9 mL of this diluted ABTS⁺ solution was added to 100 μ L of each compound to be tested (aqueous and hydro-ethanolic extracts, dichloromethane and aqueous fractions) in different test tubes then shaken vigorously. The initial concentration of these test compounds is 10 mg/mL. After shaking, the mixture was incubated for 6 minutes in the dark ($T = 30 \pm 2$ °C). The residual absorbance of the ABTS⁺ radical was then measured at 734 nm with a UV-visible spectrophotometer and should be between 20%-80% of the absorbance of the white. The tests were carried out in triplicate and the results were expressed in μ mol Trolox equivalent per liter of extract (μ mol TE/L). The inhibition rate (%I) of ABTS⁺ was expressed as follows:

$$\% I = [(A_0 - \text{Compound Abs}) / A_0] \times 100$$

A_0 = diluted ABTS absorbance. Compound Abs = diluted ABTS absorbance + sample

2-4 Spectrophotometric determination of certain secondary metabolites

2-4-1 Determination of total flavonoids

The method of Marinova *et al.* (2005) was used for the determination of total flavonoids. It consisted of putting a volume of 0,75 mL of sodium nitrite (NaNO_2) at 5% (m/v) into a 25 mL flask, adding 2,5 mL of extract then homogenizing it. To this mixture, 0,75 mL of aluminum chloride (AlCl_3) at 10% (m/v) was added, then incubated for 6 minutes in the dark.

After the incubation, a volume of 5 mL of sodium hydroxide (1N NaOH) was added and then the volume was made up to 25 mL with distilled water. The mixture was shaken vigorously before being measured with a UV-visible spectrophotometer. The reading was taken at 510 nm. The tests were carried out in triplicate. The flavonoid content was expressed in grams per liter of quercetin equivalent extract.

2-4-2 Determination of total polyphenols

The determination of total polyphenols was carried out according to the method described by Wood *et al.* (2002). To do this, to a volume of 30 μ L of extract or fraction, 2.5 mL of Folin-Ciocalteu reagent diluted 1/10 was added. The mixture obtained was kept for 2 minutes in the dark at room temperature (27 ± 3 °C) then 2 mL of sodium carbonate solution at 75 g/L was added and then homogenized. The solution obtained was then incubated at 50°C for 15 minutes. The absorbance reading was carried out with a UV-visible spectrophotometer at a wavelength of 760 nm against a blank consisting of distilled water. Gallic acid was used as a reference standard for the quantification of total polyphenol contents expressed in grams per liter of gallic acid equivalent extract (g.L⁻¹, Eq AG). The tests were carried out in triplicate for each sample.

2-4-3 Dosage of total tannins

The condensed tannin content was determined according to the method described by Julkunen-Titto (1985). To carry it out, a volume of 50 mL of each fraction or the hydroalcoholic extract was added to 1500 μ L of the 4% solution of vanillin in methanol then stirred vigorously. To this mixture, 750 μ L of concentrated hydrochloric acid was added and the whole mixture was then left to stand at room temperature for 20 minutes. The absorbance was measured at a wavelength of 550 nm against a blank consisting of the 4% solution of vanillin in methanol. The tests were carried out in triplicate for each sample. A stock solution of tannic acid was used as a reference standard for the establishment of the calibration curve and for the quantification of the contents of condensed tannins expressed in milligram equivalent of tannic acid per gram of dry matter (mg EAT /g of dry matter). The tests were carried out in triplicate for each sample.

2-5 Statistical analyzes

The curves and histograms are drawn using Microsoft Excel 2013 and GraphPad Prism 5 software. The IC₅₀ values (50% inhibitory concentration) were calculated by the linear regression method from the curve [% inhibition = f (concentrations)].

RESULTS

1- Antioxidant activity by the DPPH test

The antioxidant activity of extracts ((aqueous (Aq) and hydro-ethanolic (HOH)) and fractions (dichloromethane (DCM) and aqueous (Faq)) of *Talinum triangulare* leaves and that of ascorbic acid (vitamin C) was represented by graphs showing the variation in the percentage of free radical inhibitory power as a function of the concentration of each compound (figure 1 and 2). The DCM and Faq fractions of *Talinum triangulare* leaves gave respective IC_{50} s of 0,9 and 2,3 mg/mL. As for the aqueous (Aq) and hydro-ethanolic (HOH) extracts, their IC_{50} could not be defined from the linear regression equations of the graphs. Regarding vitamin C (reference molecule), it provided an IC_{50} of 3,056 μ g/mL. It is also noted that the reduction of free radicals at the level of the two fractions (DCM and Faq) and the reference molecule (vitamin C) is a function of the concentration of the substance used.

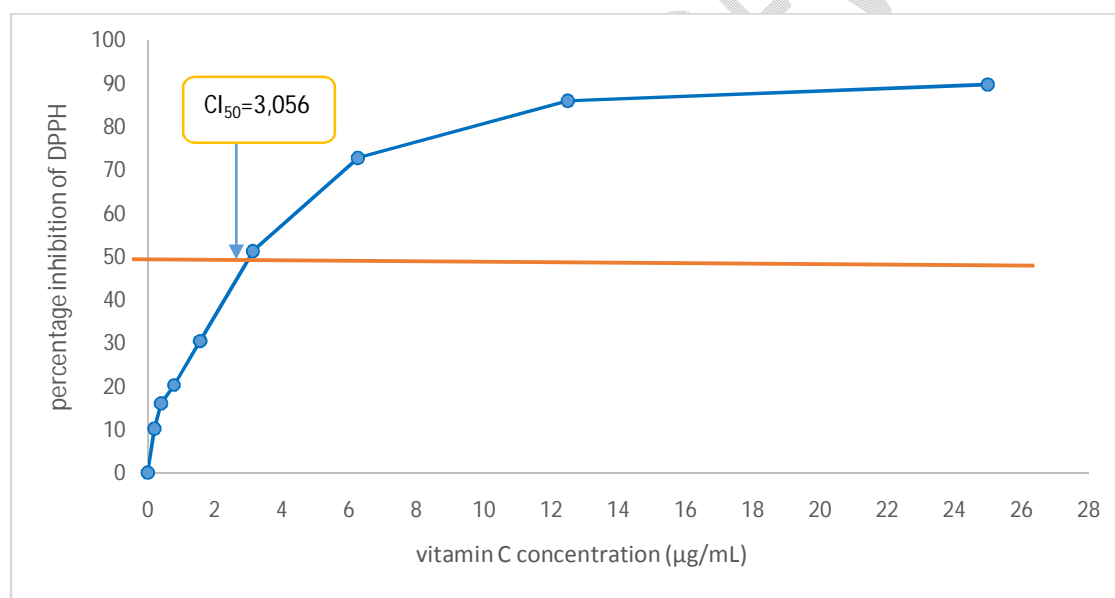


Figure 1: Percentage of DPPH inhibition as a function of different concentrations of ascorbic acid (reference molecule)

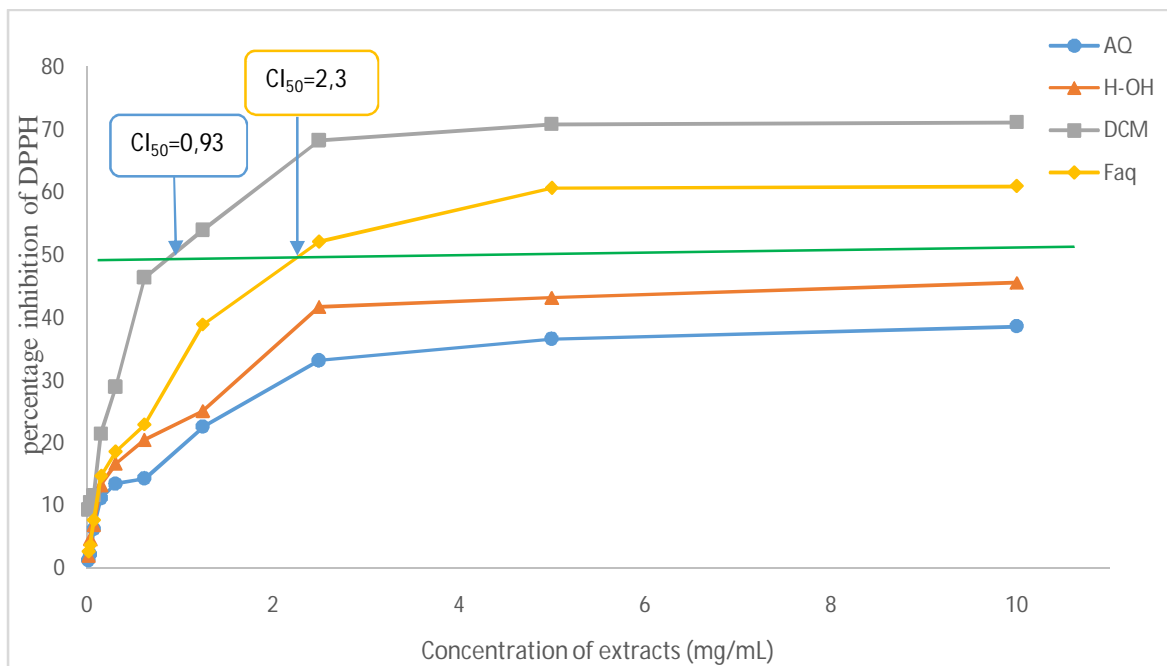


Figure 2: Percentage of DPPH inhibition as a function of concentrations of various extracts and fractions of *Talinum triangulare* leaves

2- Results of antioxidant activity by ABTS⁺

Figure 3 shows the proton trapping capacity of the cationic radical ABTS⁺ of the various products used (plant extracts and fractions). These results generally reveal that the products requested inhibited the absorbance of the ABTS⁺ radical. However, the percentage of inhibition is greater for the DCM fraction (41,59%) than that of Faq (40,59%). While that of Faq is more remarkable than that of the HOH extract (38,29%). Of the two extracts, only the Aq extract has the lowest percentage of inhibition (25,51%).

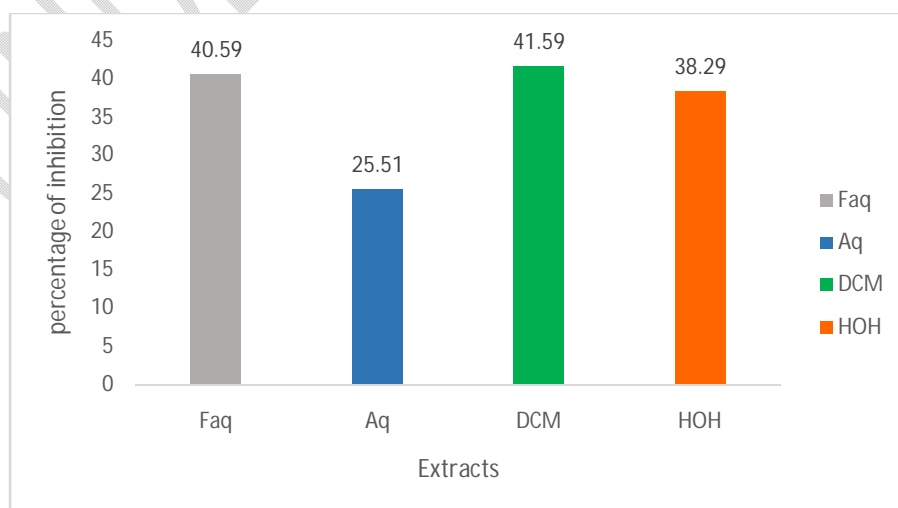


Figure 3: Percentage of inhibition of the absorbance of the ABTS⁺ radical various extracts and fractions of *Talinum triangulare* leaves

3- Total flavonoid contents

Figure 4 is the result of the total flavonoid contents of the extracts (aqueous and hydro-ethanolic) and fractions (DCM and Faq) of the leaves of *Talinum triangulare* (Talinaceae). It generally reveals that the aqueous extract (Aq) contains more total flavonoids ($10,16667 \pm 0,289$ mg EQ/g of extract) than the DCM fraction and the HOH extract with approximately equal respective values of $2,16667 \pm 0,577$ and $1,8333 \pm 0,577$ mg EQ/g of extract. As for the Faq fraction, it is characterized by a low presence of total flavonoids ($0,5 \pm 0.00$ mg EQ/g).

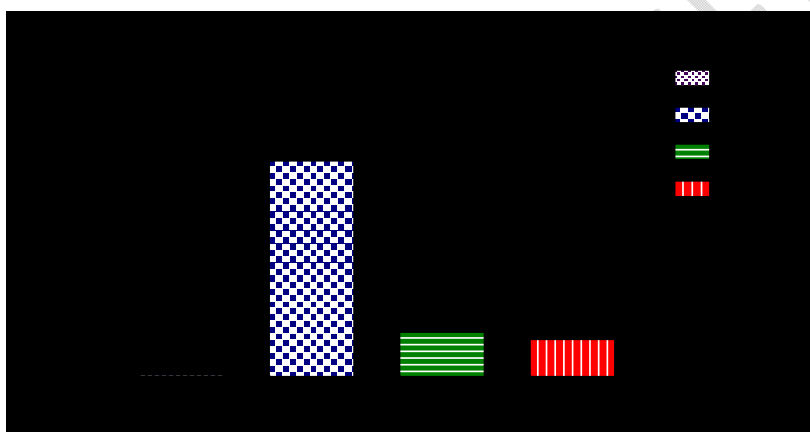


Figure 4: Total flavonoid contents of the Aq and HOH extracts, and of the DCM and Faq fractions of the leaves of *Talinum triangulare* (Talinaceae).

4- Total polyphenol contents

The results of the polyphenol contents are presented in Figure 5. It should generally be noted that this content is greater in the HOH extract ($4,8333 \pm 0,289$ mg EAG/g) than in the Faq fraction ($4,5 \pm 0,289$ mg EAG/g), $0,500$ mg EAG/g). After these, follow the Aq extract ($4,333 \pm 0,289$ mg EAG/g) and the DCM fraction ($3,8333 \pm 0,289$ mg EAG/g).

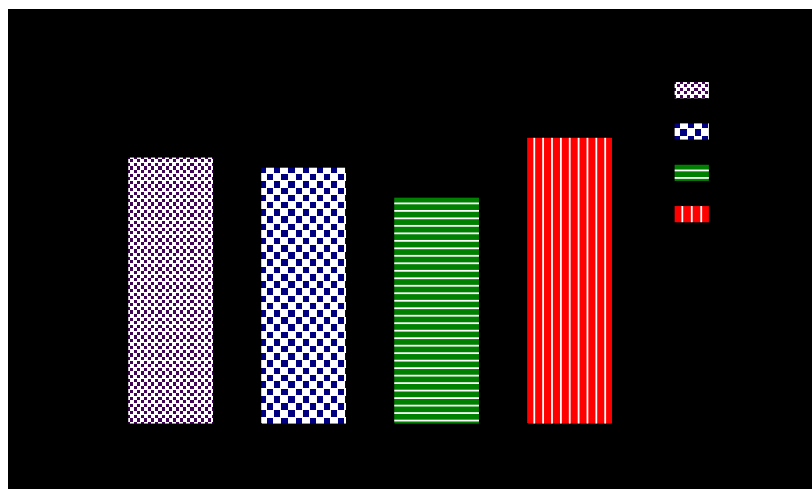


Figure 5: Total polyphenol contents of the Aq and HOH extracts, and of the DCM and Faq fractions of the leaves of *Talinumtriangulare* (Talinaceae).

5- Total tannin contents

The results of the total tannin dosage test are given in Figure 6. They show overall that the total tannin content is relatively low in all of the *Talinumtriangulare* compounds studied. However, the tannin level is a little more abundant in the HOH extract ($3,3228333 \pm 0,0254 \mu\text{g}$ EAT/g of dry extract) than in the Aq extract ($2,970667 \pm 0,00318 \mu\text{g}$ EAT/ g of dry extract). After these, the DCM fraction has more total tannins than the Faq fraction with respective contents of $2,5096667 \pm 0,00029$ and $1,835333 \pm 0,01384 \mu\text{g}$ EAT/g of dry extract.

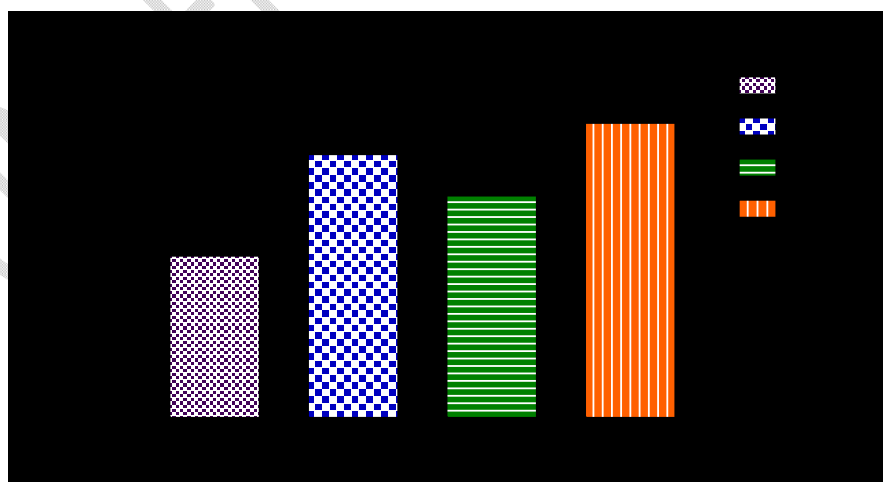


Figure 6: Total tannin contents of the Aq and HOH extracts, and of the DCM and Faq fractions of the leaves of *Talinumtriangulare* (Talinaceae).

DISCUSSION

The evaluation of the antioxidant activity of the 70% aqueous and hydro-ethanolic extracts, as well as the residual dichloromethane and aqueous fractions of *Talinum triangulare*, reveals respective IC_{50} s of 0,9 and 2,3 mg/mL for the fractions. The aqueous and hydro-ethanolic extracts did not allow the IC_{50} to be determined using the DPPH test. In comparison, vitamin C, used as a reference molecule, showed an IC_{50} of 3,056 μ g/mL. These results suggest through the inhibition activity curves that the reduction of free radicals is a function of the concentration of the substances tested, confirming the dose-dependent nature of the antioxidant activity. Compared to the work of Kouakou (2022), who reported IC_{50} s of 0,398 and 0,235 mg/mL for methanolic extracts of Sheahulls and cakes, *Talinum triangulare* fractions show lower anti-radical activity. Vitamin C is approximately 294 times (0,9 mg/3,056 μ g) more effective than the fraction dichloromethane and approximately 752 times (2,3 mg/3,056 μ g) more effective than the residual aqueous fraction, highlighting the superior effectiveness of vitamin C as a pure antioxidant. In contrast, the dichloromethane fraction is approximately twice as effective as the residual aqueous fraction (2,3/0,9). This result is supported by the work of Athamena *et al.* (2010), who showed that the percentage of inhibition of free radicals varies depending on the solvent used for the extraction and the concentrations of the anti-radical compounds. The results of Tidiane *et al.* (2021) report a lower IC_{50} of vitamin C in *Vitellaria paradoxa* (shea) extract, but our IC_{50} for vitamin C (3,056 μ g/mL) is approximately three times higher than theirs, which may reflect differences in sample quality or experimental conditions. According to Barkat and Laib (2011), a lower IC_{50} is associated with better antioxidant activity. However, despite the higher IC_{50} of *Talinum triangulare* fractions compared to vitamin C, their antioxidant activity remains significant.

The results of the ABTS⁺ radical absorbance inhibition test revealed a higher percentage for the dichloromethane fraction (41,59%) compared to the residual aqueous fraction (40,59%), the hydro-ethanolic extract (38,29 %), and the aqueous extract (25,51%). They thus corroborate those obtained with the DPPH test on the antioxidant capacity of the different compounds contained in the plant products tested and show comparable performance, but highlight the hydro-ethanolic extract and the aqueous extract as having antioxidant capacities notable, although lower than the dichloromethane fraction. This study also highlighted the presence of phenolic compounds such as flavonoids, polyphenols and total tannins at different proportions in the plant products used. In fact, they are present in

descending order when switching from one plant product to another. Thus, the content of total flavonoids is $10,16667 \pm 0,289$ mg EQ/g for the aqueous extract, $2,16667 \pm 0,577$ mg EQ/g for the dichloromethane fraction, $1,8333 \pm 0,577$ mg EQ/g for the hydroethanolic extract and $0,5 \pm 0,00$ mg EQ/g of extract for the residual aqueous fraction. Regarding the content of total polyphenols, it is $4,8333 \pm 0,289$ mg EAG/g for the hydro-ethanolic extract, $4,5 \pm 0,500$ mg EAG/g for the residual aqueous fraction, $4,333 \pm 0,289$ mg EAG/g for the aqueous extract and $3,8333 \pm 0,289$ mg EAG/g for the dichloromethane fraction. As for the total tannin content, it is $3,3228333 \pm 0,0254$ μ g EAT/g for the hydroethanolic extract, $2,970667 \pm 0,00318$ μ g EAT/g for the aqueous extract, and $2,5096667 \pm 0,00029$ μ g EAT/g and $1,835333 \pm 0,01384$ μ g EAT/g of dry extract respectively for the dichloromethane fraction and the residual aqueous fraction. These results confirm the observations of N'guessan *et al.* (2007) and Bidié *et al.* (2011), who found a correlation between the level of total phenols and antiradical activity. Furthermore, the work of Chen and Ho (1995) demonstrated that the functional groups of phenolic compounds, such as flavonoids and polyphenols, are capable of donating electrons or protons to neutralize free radicals. Thus, the antioxidant activity of the requested plant products previously demonstrated by the DDPH test and the ABTS⁺ radical-cation reduction test could be due to the presence of these phenolic compounds (polyphenols, flavonoids and total tannins) in the leaves of *Talinum triangulare*. The results of this study are different from those of Soro (2023) who revealed the absence of phenolic compounds such as polyphenols and total flavonoids in *Rhynchosporacorymbosa* extract.

CONCLUSION

The study demonstrated that *Talinum triangulare* leaf extracts and fractions have variable antioxidant activity, with notable effectiveness of the dichloromethane fraction. Although vitamin C remains the most potent antioxidant among the compounds tested, the plant's fractions offer significant antioxidant potential, justifying their traditional use in the treatment of malaria. The results suggest that phenolic compounds present in *Talinum triangulare* compounds contribute to this antioxidant activity. These results support the interest of this plant in traditional pharmacopoeia and encourage further research to isolate and characterize the active compounds responsible for its therapeutic properties.

REFERENCES

- Athamena S., Chalghem I., Kassah-Laouar A., Laroui S. & Khebri S. (2010). Antioxidant and antimicrobial activity of extracts of *Cuminum cyminum* L. *Lebanese Science Journal*, 11(1): 69-81.
- Bagayoko K.N. (2008). Incidence and lethality of serious and complicated malaria in the pediatric intensive care unit of CHU Gabriel TOURE. Doctoral thesis in Medicine, Faculty of Medicine, Pharmacy and Odontostomatology of Bamako, Mali, 89 p.
- Barkat M. & Laib I. (2011). Chemical composition and antioxidant activity of the essential oil of dry flowers of *Lavandula officinalis*. Vol.6, pp.46-54.
- Benzie I.F.F. and Szeto Y.T. (1999). Total Antioxidant Capacity of Teas by the Ferric Reducing/Antioxidant Power Assay. *Journal Agricultural Food Chemical*, 47(2), p. 633 - 636.
- Bidie A.P., N'guessan B.B., Yapo A.F., N'guessan J.D., Djaman A.J. (2011). Antioxidant activities of ten medicinal plants from the Ivorian pharmacopoeia. *Science & Nature* Vol. 8 No. 1: 1 - 11 (2011)
- Bolou G.E.K., Attioua B., N'guessan A.C., Coulibaly A., N'guessan J.D & Djaman A.J., (2011). *In vitro* evaluation of the antibacterial activity of *Terminalia glaucescens* plant extracts, on *Salmonella typhi* and *Salmonella Typhimurium*. *Bulletin of the Royal Society of Sciences*, 80:772-790.
- Brand-Williams W., Cuvelier M.E., Berset CLWT. (1995). Use of Radical Method to Evaluate Antioxidant Activity. *LWT-Food Science and Technology*, 1995; 28 (1), 25-30.
- Chen C.W. & Ho C.T., (1995). Antioxidant properties of polyphenols extracted from green tea and black tea. *J Lipids*, 2:35-46.
- Choong C., Van-Den T.T., Roger F. & Roger M.C.F.L. (2007). Antioxidant activities, phenolic and beta-carotene contents of sweet potato genotypes with varying flesh colors. *Food Chemistry*, 103(3):829-838.
- Gentilini M., Dufflo B., (1993). Malaria In: *Medicine Tropical* ed, Flammarion, 1993 81-108.
- Hemmer C.J., Lehr H.A., Westphal K., Unverricht M., Kratzius M. & Reisinger E.C. (2005). "*Plasmodium falciparum* Malaria: reduction of endothelial cell apoptosis *in vitro*." *Infect Immun* 73(3): 1764-1770.
- Julkunen-Titto R., (1985). Phenolic constituents in the leaves of Northern Willows: Methods for the Analysis of Certain Phenolics. *J. Agric. Food Chem.*, 33: 213-217.

Kouakou A.B (2022). Antioxidant, antimicrobial and healing effectiveness of cosmetic products formulated from sheanut shells and cakes (Vitellaria paradoxa). Agrifood Biotechnology Thesis. UFR Biosciences, Félix Houphouët-Boigny University, Ivory Coast, 129 p.

Mariam K., Obouayeba A.P., Ackah B.J.A.A., Dosso K. (2024). Phytochemical sorting and biotolerance of an improved traditional medicine used in the treatment of hepatitis B in Côte d'Ivoire. *World Journal of Pharmaceutical and Life Sciences (WJPLS)*, 10(3): 25-36.

Marinova D., Ribarova F., Atanassova M. (2005). Total phenolics in Bulgarian Fruits and vegetables. *Journal of the University of Chemical Technology and Metallurgy*, T.40, No. 3, p. 255-260.

Molyneux P. (2004). The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. *Songklanakar Journal of Sciences and Technology*, 26(2), p. 211 -219.

N'guessan J.D., Zirihi G.N., Kra A.K.M., Kouakou K., Djaman A.J. & Guede-Guina F. (2007). Free radical scavenging activity, flavonoid and phenolic contents of selected Ivorian plants. *IJONAS*, 4: 425-429

Nkasa H.L., Clément I.C.L., Muzomwe M.J.C., Masengo E.I., Mumba C.M., Taba K.M. (2020). Phytochemical screening and antibacterial activity of phytomedicine matthesia, a drug use against buruli ulcer in Democratic Republic of Congo (DRC). *European Journal of Pharmaceutical and Medical Research (EJPMR)*, 7(2):52-56.

Okou O.C., Tano K.D., Koffi A.J., Koffi A.F., Yavo W., and Djaman A.J. (2019). Evaluation of the antiplasmodial activity of *talinum triangulare* (talinceae), a west African food plant. *European Journal Of Pharmaceutical And Medical Research*.

WHO (2023). <https://www.afro.who.int>. World Malaria Day 2024.

Pincemail J., Bonjean K., Cayeux K. & Defraigne J.O. (2002). "Physiological action of antioxidant defense." *Clinical Nutrition and Metabolism* 16:233-239.

Salery, M.R. (2007). Antimalarial activity of girolin: *invitro* and *invivo* study. National Veterinary School of Toulouse, Paul-Sabatier University of Toulouse. Veterinary Medicine Thesis: 158 p.

Soro M. (2023). Identification and characterization of secondary metabolites that inhibit the polymerization of Hb_s hemoglobins from *Rhynchosporacorymbosa* and *Olax subscorpioidea*;

plants used in the treatment of sickle cell disease in the Poro Region (Ivory Coast). Doctoral Thesis in Biology-Health, Specialty: Biochemistry and Pharmacology of Natural Substances, UFR Agroforestry, Jean Lorougnon Guédé University (Daloa), Ivory Coast, 179p.

Swarna J., & Ravindhran R. (2013). Pharmacognostical and Phytochemical Evaluation of *Talinum triangulare* (Jacq.) Willd. *International Journal of Pharmacy and Pharmaceutical Sciences*, 5(2): 249-256.

Tagne M.L.L. (2021). Malaria: knowledge, prevention practices and therapeutic routes in Kouloba, Sogonafing and point G. State Doctorate Thesis in Medicine, Faculty of Medicine and Odontostomatology (FMOS), University of Sciences, Techniques and Technologies of Bamako, Mali, 71p.

Tano K.D. (2016). Study of the antiplasmodial activity of various extracts of *Terminalia glaucescens* (Combretaceae) and *Erigeron floribundus* (Asteraceae). Toxicological profile for the formulation of improved traditional antimalarial medicines (ATMs). Single thesis on Valorization of natural substances (Option: Parasitology), UFR of Pharmaceutical and Biological Sciences, Félix Houphouët-Boigny University, Ivory Coast, 237 p.

Tidiane K., Ouattara G.A., Monon K., Abdoulaye T. & Karamoko O. (2021). Phytochemical study and antioxidant activity of stem bark extracts of *Vitellaria paradoxa* C.F. Gaertn, a medicinal plant used in the North of Ivory Coast. *European Scientific Journal*, 17(34), 241. <https://doi.org/10.19044/esj.2021.v17n34p241>

Wood J.E., Senthilmohana S.T., Peskin A.V. (2002). Antioxidant activity of procyanidin-containing plant extracts at different pHs. *Food Chemistry*, 77(2): 155–161.

Zirihi G.N., Kra A.K.M. & Guédé-Guina F. (2003). Evaluation of the antifungal activity of *Microglossa pyrifolia* (Lamarck, O. Kuntze) (Asteraceae) "PYMI" on the in vitro growth of *Candida albicans*. *Revue de Médecine et de Pharmacie*, 17: 11-18.